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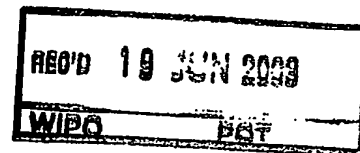
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Patentanmeldung Nr.   Patent application No.   Demande de brevet n°

02077260.4

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
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If no title is shown please refer to the description.
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Magnetic resonance method

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Magnetic resonance method

The invention relates to a magnetic resonance (MR) method for the imaging of an object arranged in a steady magnetic field, whereas the following steps being repeatedly executed according to said method:

excitation of spins in a part of the object,

5   slices are selected within the Field-of-View (FOV) of the object to be scanned,

said selected slices are in oblique relationship with respect to the original slices, and

measurement of MR signals along a predetermined trajectory containing a plurality of lines in said slices in k-space by application of a read gradient and other gradients.

The invention also relates to an MR device for carrying out such a method.

10   It is generally known in multiple slice imaging techniques that parallel slices are imaged in such a manner that if parallel slices are rotated they are kept at the same position to each other in order to obtain a proper image of the object. However, backfolding artifacts cannot always be prevented as parts outside of the rectangular FOV will be covered also by the scan.

15   In magnetic resonance imaging there is further a general tendency to obtain acceptable images within shorter periods of time. For this reason the sensitivity encoding method called "SENSE" has recently been developed by the Institute of Biomedical Engineering and Medical Informations, University and ETH Zürich, Switzerland. The SENSE method is based on an algorithm which acts directly on the image as detected by the

20   coils of the magnetic resonance apparatus and which subsequent encoding steps can be skipped and hence an acceleration of the signal acquisition for imaging by a factor of about two to three can be obtained. Crucial for the SENSE method is the knowledge of the sensitivity of the coils which are arranged in so called sensitivity maps. In order to accelerate this method there are proposals to use raw sensitivity maps which can be obtained through

25   division by either the "sum-of-squares" of the single coil references or by an optional body coil reference (see e.g. K. Pruessmann et. al. in Proc. ISMRM, 1998, abstracts pp. 579, 799, 803 and 2087). In fact the SENSE method allows for a decrease in scan time by deliberately undersampling k-space, i.e. deliberately selecting a scanning Field-of-View (FOV) that is smaller than the object to be acquired. From this undersampling fold-over artifacts are

obtained which can be resolved or unfolded by the use of the knowledge of a set of distinct coils having different coil sensitivity patterns. The undersampling can be in either one of both phase-encoding directions.

5   If the object exceeds the FOV to be reconstructed (in the phase encoding SENSE direction) residual backfolding will occur with the SENSE method which will be apparent somewhere in the middle of the image.

It is an object of the present invention to prevent forming of backfolding artifacts both with and without the SENSE technique as mentioned above.

This object has been solved by the method with the features as described in

10   Claim 1.

The method according to the present invention has the important advantage, that in a very easy manner the forming of residual backfolding artifacts is prevented.

These and other advantages of the invention are disclosed in the dependent claims and in the following description in which an exemplified embodiment of the invention

15   is described with respect to the accompanying drawings. It shows:

Fig. 1 an MR apparatus for carrying out the method, and

Fig. 2 three panes to explain the inventive method.

20

In Figure 1 a magnetic resonance apparatus 1 is diagrammatically shown. The apparatus comprises a set of main magnetic coils 2 for generating a stationary homogeneous main magnetic field and several sets of gradient coils 3, 4 and 5 for superimposing on to the

25   main magnetic field additional magnetic fields with controllable strength and having a gradient in a selected direction. Conventionally, the direction of the main magnetic field is labeled the z direction, the two directions perpendicular thereto are the x and y directions. The gradient coils are energized via a power supply 11. The apparatus further comprises excitation means 6 in the form of a so-called body coil for emitting radio-frequency pulses

30   (RF-pulses) to an object or body 7, the excitation means 6 being coupled to modulating means 8 for generating and modulating of the RF-pulses. Also provided are means for receiving the MR-signals, these means can be identical to the excitation means 6 or be

distribution, whereas a receiver coil is a coil used close to one side of a (part of a) body. A receiver coil has generally a limited field of view, a high sensitivity but an inhomogeneous spatial sensitivity distribution. A send-receive switch 9 is arranged to separate the received signals from the excitation pulses. The received magnetic resonance signals are input to

5   receiving and demodulating means 10. The excitation means 6 and modulating means 8 and the power supply 11 for the gradient coils 3, 4 and 5 are steered by a control system 12 to generate a predetermined sequence of RF-pulses and gradient field pulses. The demodulation means is coupled to data processing means 14, for example a computer, for transformation of the received signals into an image that can be made visible, for example on a visual display

10   unit 15.

If the magnetic resonance apparatus 1 is put into operation with an object or body 7 placed in the magnetic field, a small excess of magnetic dipole moments (nuclear or electron spins) in the body will be aligned in the direction of the magnetic field. In equilibrium, this causes a net magnetization M_0 in the material of the body 7, directed in

15   parallel with the magnetic field. In the apparatus 1 the macroscopic magnetization M_0 is manipulated by radiating to the body RF-pulses having a frequency equal to the Larmor frequency of the dipole moments, thereby bringing the dipole moments in an exited state and re-orienting the magnetization M_0. By applying the proper RF-pulses, a rotation of the macroscopic magnetization is obtained, the angle of rotation is called the flip-angle. The

20   introduction of variations in the magnetic field by applying gradient magnetic fields influences the behavior of the magnetization locally. After the application of RF-pulses, the changed magnetization will tend to return to a state of thermal equilibrium in the magnetic field, emitting radiation in the process. A well chosen sequence of RF-pulses and gradient field pulses causes the radiation to be emitted as (decaying) magnetic resonance signals

25   which provide spatial information about the density and/or relaxation times of a certain type of nuclei, for example hydrogen nuclei, and the substance in which they occur. By analysis of the emitted signals, picked up by the coil 6 or with the receiver coil array 16 — and by presentation of it in the form of images, information about the internal structure of the object or body 7 is accessible. The decaying magnetic resonance signal directly after the excitation

30   is called FID (Free Induction Decay). By proper application of the gradients and/or application of additional excitation (RF) pulses also an echo of the FID may be produced and used to derive image information. For a more detailed description of magnetic resonance imaging (MRI) and MRI-devices reference is made to the extensive literature on this subject,

for example to the book "Magnetic Resonance Imaging", by M.T. Vlaardingerbroek, Springer Verlag, 1996.

In Figure 2a an object 20 to be scanned (e.g. the heart) which is surrounded by tissue 21 (e.g. the human body) is shown which will be scanned with the above mentioned

5   MR apparatus 1 in parallel slices 22 which are set by the user. Imaging occurs in a rectangular area defined by the Field-of-View (FOV) and the Rectangular Field-of-View (RFOV) which can be freely defined by the operator of the MR machine. The RFOV direction is also the foldover direction (and can be also a SENSE encoding direction) In our example in Figure 2, the width of these slices 21 establish the FOV of the scan, and the

10   height of the slices 22 defines the RFOV. As can be seen the longitudinal axis 23 of the object to be scanned is at an angle α to the direction z of the RFOV. Thus, according to Figure 2b the slices 22 are rotated over an angle α in order to obtain an improved imaging of the object 20. However, since the slices 22 are normally kept in an exact parallel relationship, part of the slices 22 fall out of the area as covered by the original RFOV. When the angle α is

15   for example 30° and the thickness B of the slices 22 is 1 cm with a gap of 0 cm between the slices 22 than the area 25 depicted in dashed lines will cover 5 cm in vertical direction y. Now, according to Fig. 2c the rotated slices 22 are shifted in their longitudinal direction over a distance B * sin α so that the start positions and the end positions of the slices 22 coincide approximately with the area of the RFOV. Thus, the slices 22 do not fall outside of the

20   original RFOV from the slices before rotation (Fig. 2a) and any tissue outside of that area will not be covered any more, thus preventing any backfolding artifacts. Especially for fast sampling methods like SENSE this is crucial as residual backfolding artifacts would lead to serious artifacts which cannot be suppressed easily. Additionally to the shift of the slices 22 the lines to be scanned within the slices 24 can have a uniform offset at a direction

25   perpendicular to the direction of the respective slice 22. Additionally or alternatively the original RFOV may be diminished which leads to faster scanning.

Instead of rotating the slices 22 also an oblique direction with respect to the rectangular orientation of the original slices can be selected for scanning the slices 22.

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CLAIMS:

1.   A magnetic resonance imaging method for forming an image of an object from a plurality of signals acquired by an array of multiple receiver antennae, wherein

-          spins are excited in a part of the object,

-          slices with a predetermined Field-of-View are selected for scanning the object,

5   -   said selected slices are scanned in an oblique relationship with respect to the scanning direction of the original slices,

-          MR signals are measured along a predetermined trajectory containing a plurality of lines in said slices in k-space by application of a read gradient and other gradients,

10   characterized in that said slices are shifted in lengthwise direction obtaining a staggered arrangement of said slices such that the beginning and the end of each of said slices are at least approximately within the area of interest.

2.   A method as claimed in claim 1, characterized in that the selected slices are
15   rotated uniformly over a predetermined angle in order to obtain said oblique relationship.

3.   A method as claimed in claim 1 or 2, characterized in that the shift of any subsequent slice with respect to the prior one is shifted over the slice thickness multiplied with the sinus of the rotating angle.

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4.   A method as claimed in claim 3, characterized in that lines to be scanned within each of said slices have a uniform offset along a line perpendicular to the direction of the slice.

25   5.   A magnetic resonance imaging apparatus for obtaining an MR image from a plurality of signals comprising:

means for excitation of spins in a part of the object,

means for selection of slices with a predetermined Field-of-View for scanning the object,

means for selecting said slices in an oblique relationship with respect to the original slices,

means for measuring MR signals along a predetermined trajectory containing a plurality of lines in said slices in k-space by application of a read gradient and other gradients,

means for setting the scanning direction of said slices in such a manner that tissue outside the area of interest is not covered, and

5   means for shifting said slices in lengthwise direction obtaining a staggered arrangement of said slices such that the beginning and the end of each of said slices are at least approximately within the area of interest.

6.   A magnetic resonance imaging apparatus as claimed in claim 5, further

10   comprising means for rotating the selected slices uniformly over a predetermined angle in order to obtain said oblique relationship.

7.   A computer program product stored on a computer usable medium for forming an image by means of the magnetic resonance method, comprising a computer readable

15   program means for causing the computer to control the execution of:

excitation of spins in a part of the object,

selection of slices with a predetermined Field-of-View,

selecting said slices to be scanned in an oblique relationship with respect to the original slices,

20   measuring MR signals along a predetermined trajectory containing a plurality of lines in said slices in k-space by application of a read gradient and other gradients,

setting the scanning direction of said slices in such a manner that tissue outside the area of interest is not covered, and

shifting said slices in lengthwise direction obtaining a staggered arrangement of said slices

25   such that the beginning and the end of each of said slices are at least approximately within the area covered by the slices before rotation.

8.   A computer program product according to Claim 7, comprising rotating the slices uniformly over a predetermined angle in order to obtain said oblique relationship.

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9.   A computer program product according to claim 7 or 8, comprising providing of a uniform offset along a line perpendicular to the direction of the slice for lines to be

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ABSTRACT:

        A magnetic resonance imaging method for forming an image of an object from
a plurality of signals acquired by an array of multiple receiver antennae, wherein spins are
excited in a part of the object. Slices (22) are selected with a predetermined Field-of-View for
scanning the object and are rotated uniformly over a predetermined angle. MR signals are
5   measured along a predetermined trajectory containing a plurality of lines said slices in k-
space by application of a read gradient and other gradients. Further the slices (24) are shifted
in lengthwise direction obtaining a staggered arrangement such that the beginning and the
end of each of said slices are at least approximately within the area covered by the slices
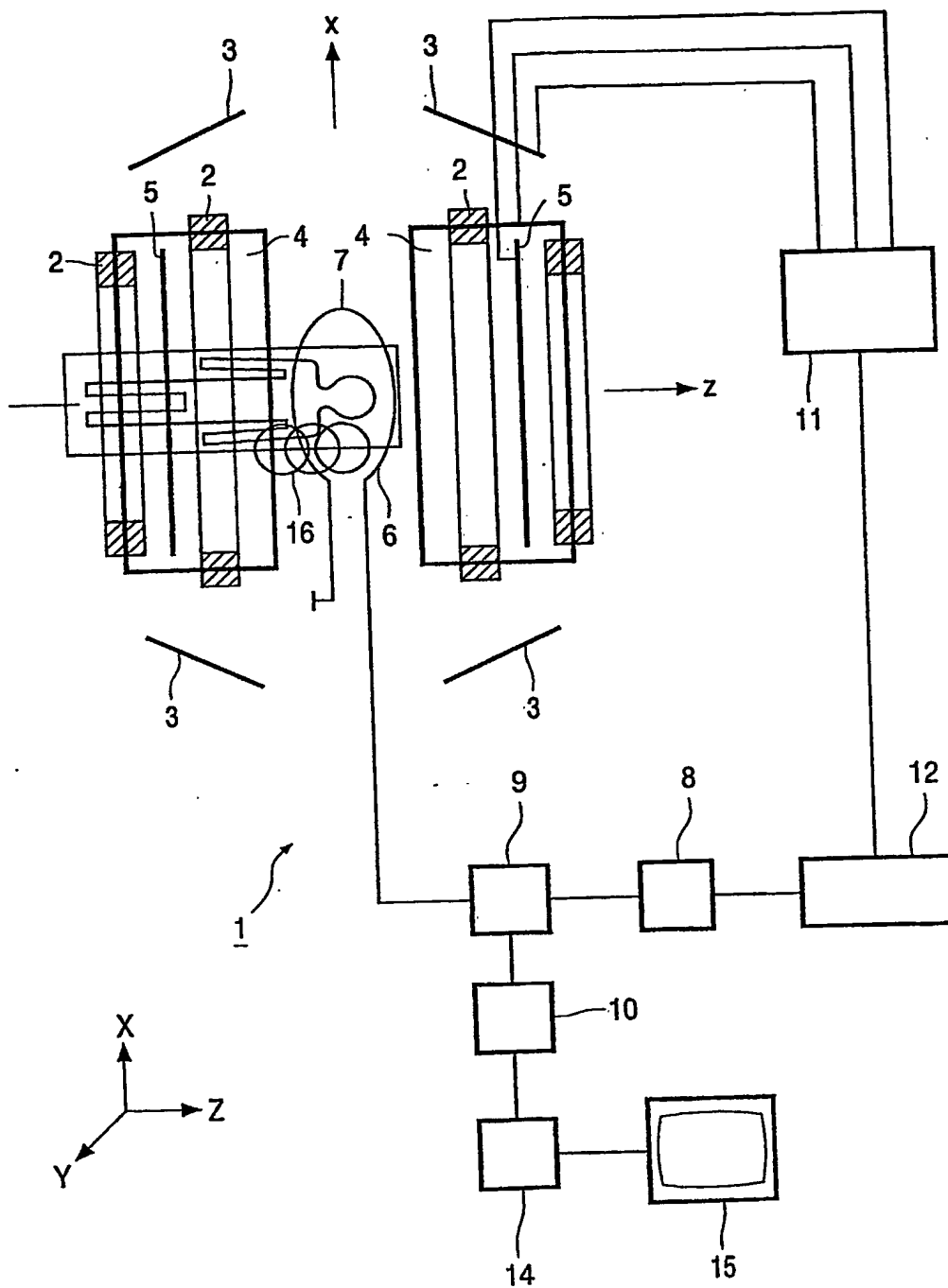before rotation.

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(Fig. 2c)
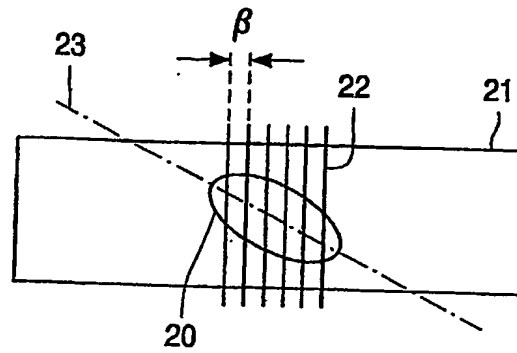
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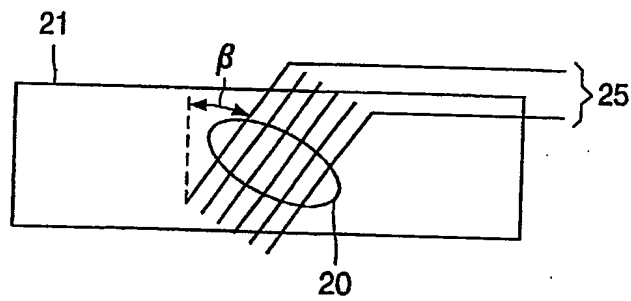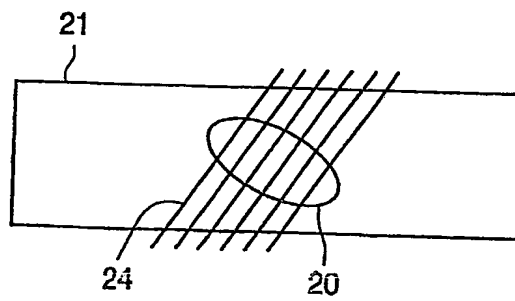1/2

FIG. 1

FIG. 2a

FIG. 2b

FIG. 2c

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